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Pavement Management Systems

-Guidelines for Municipalities-

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Pavement Management Systems: Guidelines for Municipalities

EXECUTIVE SUMMARY

"Getting the biggest bang for the buck" is a much-used phrase, but one which is particularly applicable in the effective management of funds allocated to pavements through a pavement management system.

A number of consultants now offer pavement management packages and services which vary considerably in detail, product output, and costs. This report, prepared by a task force of the Municipal Engineers Advisory Committee, reviews the packages offered by four Ontario consultants; namely:

- Barker Terp Gibson (BTG),
- Gregg and Edens (G&E),
- Pavement Management Systems (PMS), and
- Trow.

The report discusses how a municipality might make use of the pavement management systems concept, and outlines the products which are required to make up a complete minimum package.

The summary table which follows is a simple guideline defining this complete minimum package. The five "must have" elements in the guideline can be put together in stages over a two- to three-year period. Some parts of the Road Needs Study are common and parallel to requirements of a pavement management system, and these have been identified so that duplication of effort may be avoided. Optional elements offered by consultants can enhance the capabilities of the systems.

The Task Force recommends pavement management systems as a valuable tool to assist managers to optimize their pavement investments.

Table 1/ Summary

Pavement Management Systems -- Municipal Guidelines

MUST HAVE	Provided By	
	Road Needs Study	Consultant
I/ INVENTORY Sectioning	Yes. Additional sections needed for pavement structures.	ALL
Geometrics (cross-section, widths, etc.)	Yes	ALL
Structural (thicknesses, materials)	Structural Rating based on distress	Municipal Records OR by low frequency coring
History (construction, reconstruction, etc.)	From updates	Municipal Records, updates
History (maintenance, overlay, etc.)	Rating. Not specific to pavement.	Municipal Records (existing or new)
Traffic	Yes	Usually provided by municipality, OR derived from sample counts
Drainage	Some	ALL
Riding Quality (roughness)	No	PMS uses ARAN & PURD
Surface Distresses	Yes	PMS and BTG use MTC system. TROW and G&E use their own systems.
Response to Load (deflection)		ALL offer services...
- Perhaps at low frequency for Network PMS	No	
- Definitely at high frequency for Project PMS	No	PMS and BTG use Dynaflect. TROW uses FWD. G&E use Benkelman Beam.

PMS -- Municipal Guidelines (Continued)

MUST HAVE	Provided By	
	Road Needs Study	Consultant
II/ PROJECTS RANKED ACCORDING TO PRIORITY		
• Lists are separately compiled for: - primary systems - secondary systems - tertiary systems		
• Criteria for ranking are based on certain agreed inventory attributes such as riding quality, surface distress, traffic, etc. AND on desirable levels of these attributes. Summary statistics such as Pavement Quality Index (PQI) may be used.	Produced by MTC computer. Uses: - Priority Rating - Priority Guide No. This list may be arranged differently by different PMS criteria.	All consultants will produced this on request

PMS -- Municipal Guidelines (Continued)

MUST HAVE	Provided By: Road Needs Study	Provided By: Consultant
III/ NEEDS RANKED ACCORDING TO PRIORITY Take list of priority ranked projects (Item II above) and add appropriate needs, i.e. determine cost-effectiveness of alternative treatments and make recommendations based on benchmark costs for each project over the whole system(s). REVIEW this list with similar needs lists for traffic volume capacity, for sewer reconstruction (and major utilities) to determine redundancies.	Yes This list may be different than one derived by PMS.	All consultants will provide recommendations for cost-effective alternative strategies. Their evaluation techniques vary; for example, in performance prediction: - BTG uses experience plus projections by geometric progression. - Trow uses straight-line projections updated by regression curves. - G&E uses interpolated regression curves, or Markov curves in early stages. - PMS uses Markov curves, updated with experience.

PMS -- Municipal Guidelines (Continued)

MUST HAVE	Provided By: Road Needs Study	Provided By: Consultant
IV/ NETWORK PMS -- Multi-Year Plan • Take priority-ranked list of needs (Item III) and apply criteria of: - management objectives, such as other projects, industrial areas, technical, political, economic, user costs to the community; - money available and projected to be available over the planning period. • Examine delay or acceleration of each project and adjust proposed treatments as needed to optimize effectiveness of expenditures. • Examine consequences of changing budgets on average system condition. • Take Multi-Year Plans for primary, secondary and tertiary systems to Council. • Council determines money.	Effectiveness of expenditures evaluated by percent of length of deficient roads and streets in a system.	ALL consultants can develop a multi-year plan. However, there are significant differences in their capabilities, as detailed in Appendix I. For example... • G&E, and PMS, currently provide analysis of consequences of budget change on average system condition, and PMS includes analysis of delay or acceleration of projects. • BTG totals cost-effective treatments for each project in each year in the planning period. • TROW is currently working towards development of consequences program.

PMS -- Municipal Guidelines (Continued)

MUST HAVE	Provided By	
	Road Needs Study	Consultant
W/ Project PMS • Take Multi-Year Plans, Year 2 & 3 projects, and rework to reflect better design based on additional detailed information from coring and deflection studies, more accurately estimated costs based on these updated designs, and re-examine optimum timing of projects. • Develop more accurate, specific plan for Year 2 particularly, and for Year 3. Update the Multi-Year Plan annually, with accurate costs in Years 1 and 2, some accurate costs in Year 3, benchmark costs in Year 4 and subsequent years. • Resources are 'managed' for optimum effectiveness.	Not applicable.	• All consultants offer project design services based on detailed data collection. Capabilities vary, but products are all based on the same current design technology. Differences will show in concentration of consultant expertise, experience and resources in product outputs.

PMS/ Municipal Guidelines (Continued)

OPTIONAL	PROVIDED BY CONSULTANTS
Examples	
• Optimization by different objectives such as: - Minimizing agency cost. This option can lead to increased user costs to the community. - Maximizing benefits of various kinds. • Colour-coded maps showing system condition, multi-year plan, etc., as desired. • Quantities of materials in overlays, partial-depth milling, to restore crossfall within specified tolerances. • Training of municipal technical staff in PMS activities. • Access by municipal staff in any or all computerized data and related programs.	• Details of capabilities of individual consultants which are not included in Appendix I may be obtained from the consultants.

1/ BACKGROUND

An effective pavement management system is one way for a municipality to ensure that funds allocated to pavements are being used to return maximum benefits to the community -- "getting the biggest bang for the buck". Pavements constitute a major portion of the highway investment, and they contribute in large measure to the economy of an area and to the mobility of its people.

While management of a network of roads and streets implies responsibilities for ensuring adequate capacity and safety, as well as for pavement condition, the major scope of a pavement management system is really in the maintenance and rehabilitation of existing facilities. As well, some maintenance activities must be excluded which do not contribute strongly to the performance of pavements; for example, snow and ice control, traffic markings, guiderail maintenance, etc. Nevertheless, significant benefits are available for pavement management system users. A listing of benefits compiled during the TRB National Workshop on Pavement Management is reproduced in Table 2.

Table 2/ **Benefits of Operational Pavement Management Systems**

Administration	Operations (Construction and Maintenance)	Design
1. Consequences of various funding levels on the performance of the system can be demonstrated.	1. A basis for the allocation of resources is provided.	1. Evaluations of different design alternatives are provided.
2. A basis for effective allocation of resources is provided.	2. A rational basis is provided for development of improvements in specifications.	2. Data are provided to permit updating of design methodologies and specifications (e.g., materials).
3. A basis for cost allocation to users is provided.	3. Factual data are provided to permit review and evaluation of the quality of both construction and maintenance activities.	3. A rational basis for the evaluation of new materials and processes is provided.
4. Improved response to special legislative requests is possible.	4. Evaluation of alternative construction and maintenance activities can be accomplished.	4. Verification of traffic and load projections is provided. This leads, in turn, to the provision of improved traffic information.
5. Objective rather than subjective data are provided to support funding requests.	5. Information is provided for evaluation of alternative quality-control activities.	5. Evaluation of the impact of environmental factors is permitted.
6. Administrative credibility is improved.		6. Evaluation of the impacts of specification requirements and the quality of construction and maintenance operations on performance is provided.
7. Engineering input is effectively provided to the policy-making process.		7. Cost and energy optimization of design alternatives is facilitated.
8. Improved pavement performance-monitoring and forecasting are provided.		8. Cost-effective type of pavement selection is facilitated.
9. Objective information is available to describe the current condition of pavements in network.		

Over the past few years a number of different approaches to pavement management have been developed. Some of these have been still further developed and are being marketed by consultants. The services offered by consultants include measurement, collection and processing of data, as well as cost analyses of alternatives, evaluation of cost-effectiveness of different timed strategies, and development of plans for maintenance and rehabilitation which maximize returns. Examples of four systems marketed by consultants in Ontario (as of April, 1983) are given in Appendix I. Three of these systems have proprietary computer software, the other is offered to the public by the American Public Works Association (APWA). A system (PARS) under development by the Ontario Ministry of Transportation and Communications is not yet available to the public. These various approaches offered by consultants do have common elements but, because of the way their programs are tailored, and because of the differences in input requirements, it is difficult to determine their appropriateness to the requirements of any particular agency. In an effort to provide municipalities with advice on the various pavement management systems, a Municipal Engineers Advisory (MEA) Committee was formed to assist MTC in formulating guidelines. This report is the result.

1.1/ Concepts

In most agencies today, the processes for determining which suitable rehabilitation treatment to use and when to use it on any specific length of road are fairly well organized. However, it is recognized that with the advent of the computer, the capability is now available to examine for each road length, a larger number of different alternatives than was previously possible, including the same treatment applied at different times during a planning period. This makes it possible to not only choose the most cost-effective treatment, but also to choose the timing of the investment for optimum effectiveness of the funds allocated in each year of the planning period.

A pavement management system in place answers not only the questions 'what treatment?' and 'when to apply it?'; it also answers questions such as:

- Why do we need to allocate $X to pavements?

- What are the implications of postponing rehabilitation?
- What are the benefits of advancing rehabilitation?
- and so on...

1.2/ Objectives

Any agency contemplating use of a pavement management system must first decide what it expects from the system, what questions need to be answered, and how it co-ordinates with other needs, other agencies, utilities, etc. As well, in order to better satisfy the needs of very low traffic volume roads (and perhaps roads in specially defined areas), the agency should consider treating these roads as separate networks for allocation of funds.

The products which would satisfy most agencies are:

- An inventory of pavements with road sections identified and arranged in decending order of need for rehabilitation and maintenance. (The identification should be by physical objects such as intersections, changes in construction, and by administrative/political boundaries such as town lines, and maintenance districts.)

- A listing of suitable treatments for maintenance and/or rehabilitation within a planning period, for each section which is deficient in pavement condition during the period, with an evaluation for cost-effectiveness and timing of the treatment.

- An evaluation of the impact of funding constraints on the future health of the network and/or an assessment of the future funding requirements to change the system's health to a desired level within a certain time span.

- For specific projects where there is a question as to the degree of pavement strengthening needed, sufficient load response testing (Benkelman Beam, Dynaflect, Falling Weight Deflectometer) to enable detailed design to be done for the project.

Consultants who have services to offer in this area, have each developed their own product lines, but consultants should also be in a position to tailor their systems to fill the stated needs and objec-

tives of a municipality. These needs may involve widely different commitment of agency staff for the support of the management system, varying from fairly restricted input data development and use of interactive terminals for product generation, to major responsibilities for data collection, analysis, and generation of computer printouts.

1.3/ Implementation

Prior to implementation, some thought must be given to the place in the agency where pavement management fits, and to ensure there is no unnecessary duplication of effort.

Where Does It Fit? -- What is known as "network pavement management" is basically a management tool for long-term financial planning and budgeting. What is known as "project management" is a more detailed design and evaluation process for each project, leading to the preparation of the contract documents. The more detailed project management data are entered into the network management process in the years just prior to program development and updated cost estimates replace the 'average-costs' on the particular projects which were previously used. The project priorities developed in the plan for the first and second years would be prime candidates for formulating the construction program (including rehabilitation and major maintenance) for the current year. Budget approval is based on the network plan which is offered to the decision-makers and this plan is, in turn, based on detailed project design and updated costs. It must be remembered that the Pavement Management System output does not itself formulate the Roads Rehabilitation Program. The manager must assess the output information together with information from other sources concerning other programs from both his own and other agencies affecting the same streets, as well as local priorities. A construction program is then formulated to fit the allocated budget. The construction program data are used to update the inventory. The process of annual inventory update includes new data for the new projects being brought into the multi-year plan. The inventory should be completely reworked after five years.

These pavement management processes require clear organizational paths and timely informational flows for successful integration of the

planning, design, and programming phases. Responsibility for development of the plan appears to be clearly in the planning area, but extensive support is needed from the design area. However, since the planning area is generally concerned with a larger scope than pavement rehabilitation and major maintenance (e.g., intersection and capacity improvements), the pavement management data can be developed as a separate function of the design area, and the proposals for rehabilitation and maintenance work can be fed into the planning area.

Is there duplication of data with Road Needs Study? -- Municipal subsidies for roads and streets are based on the needs studies. These studies are carried out at five-year intervals with annual updates of some 20% of the system.

An inventory is produced from the survey, and two of the elements which are rated* are Item 52 (surface condition) and Item 54 (structural adequacy). The method of rating surface condition on a scale of 10 is to consider the effects of surface inadequacies as denoted by the following in ascending order of seriousness:

- noise,
- vibration,
- sway,
- excessive steering effort, and
- reduced speed.

The method of rating structural adequacy on a scale of 20 points, is to consider the relative area of occurrence of surface distress of the alligator cracking and wheeltrack cracking type, as well as the maintenance demand. Both surface condition and structural adequacy are used to determine the condition rating, together with level of service (20 points) horizontal and vertical alignment (10 points each), surface width (15 or 25 points), shoulder width (0 or 10 points), drainage (15 points), and maintenance demand (10 points). Deficiencies in the condition of a section are determined on the basis of traffic volumes, average safe speed, surface width, level of service, storm sewer adequacy, and structural adequacy. The planning intervals for deficiencies are now, one to five years, six to ten years.

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*See Appendix B of Inventory Manual Municipal Roads and Structures, Ontario Ministry of Transportation and Communications, July 1978

In pavement management systems, maintenance and rehabilitation activities are triggered by the serviceability condition, which is a composite of riding quality or roughness, quantity and quality of distresses including defects which are not obviously structural, the maintenance demand, traffic volumes, and possibly other factors as well. The data requirements for the needs study and for pavement management are similar but not the same, and they are not convertible from the needs study requirement to the pavement management requirement. However, it seems possible to convert pavement management data requirements to road needs study requirements. Certainly, the surface condition rating for the road needs study appears to be similar in concept to the measurement of riding quality, while the assessment of structural adequacy can be readily derived from a distress manifestation survey using the MTC method of evaluation*.

The five-year data collection interval of the road needs study, together with an annual update of 20% of the system, is probably acceptable for pavement management purposes. Thus it is believed feasible to obtain some of the network pavement management data at the same time that road needs studies are undertaken. However, there is also a belief that by combining these data collection requirements it will be necessary to increase the number of road and street sections so as to recognize other attributes such as construction age, thickness design, and maintenance district boundaries.

Scheduling for collection of field data will vary by agency, but better consistency with deflection measurements is obtained when testing is carried out in the spring.

1.4/ Specifications

The specifications for an implementation plan should clearly set out the following:

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*Manual for Condition Rating of Flexible Pavements -- Distress Manifestations, Chong, G.J., Phang, W.A., and Wrong, G.A., Ministry of Transportation and Communications, Ontario

- **The objectives or management system outputs or the products required.** It is believed that most municipalities would be able to put a network management system in place within one year, at a reasonable cost. Pavement management on a more detailed project basis can be followed-up selectively based on priorities identified in the network management plan, or on some other selection basis. The second and subsequent iterations of the network plan would benefit by the more accurate data inputs gained through the more detailed analyses carried out in project management.

- **The staff, facilities and responsibilities of the client agency in implementing the pavement management system.** This sets out the relationships with the contractor and defines the role of agency staff in operating the system. Details of what data is to be collected by agency staff, and when they are to be collected, can be worked out at the beginning of the job.

- **Set out the tasks which are to be done by the contractor for the primary and secondary roads network management systems and also those needed for further detailed project management.** For example for network systems the folowing tasks apply.

Task 1/ Survey of Roughness, Surface Distress, Maintenance Demand, Drainage, etc.

Details are specified for the types of measurements to be employed, the number per section/link, when they are to be done, on what part of the system (assuming inventory sections are suitably amended), and how they are to be reported.

Task 2/ Pavement Condition Index and Priority Listing Details

These are specified for the conversion of data collected in Task 1 into a Pavement Condition Index.

The weighting factors for each parameter and the method of combination into a summary statistic should be agreed on before the start of Task 1.

A listing of all roadway sections with their assigned priorities may be prepared which is also weighted, perhaps in terms of the traffic volume

and the length of the section, i.e., in terms of the amount of service provided. This priority list forms the basis for development of a five-year plan for rehabilitation and maintenance.

Task 3/ Performance Prediction

The first step in the development of a long-term plan is to estimate when there is need for action on any road section. Performance prediction models are used for this purpose. Prediction models are based on subjective experience (Markov models), on data (regression models), or on a combination of experience and data (Bayesian technique). The accuracy of prediction is certainly critical, but its importance is offset if the plan is updated annually, and as more accurate data are introduced. The prediction methodologies used by some consultants are described in Appendix A. The client agency must either accept the methodology in use by the consultant or specify a methodology.

Along with the prediction methodology, is the need to agree on criteria for acceptable levels of condition index. Usually, higher traffic volumes warrant higher acceptable levels. Once models and criteria are set, the Task 2 priority list can be examined section-by-section to determine when action is necessary.

Task 4/

Many different maintenance and rehabilitation activities can be undertaken (as shown in Figure 1) which list preventive and corrective maintenance as well as structural rehabilitation measures. The client agency must specify which of the available alternative strategies are to be considered acceptable local practice, and must provide from its records best estimates of unit cost for each of the treatments.

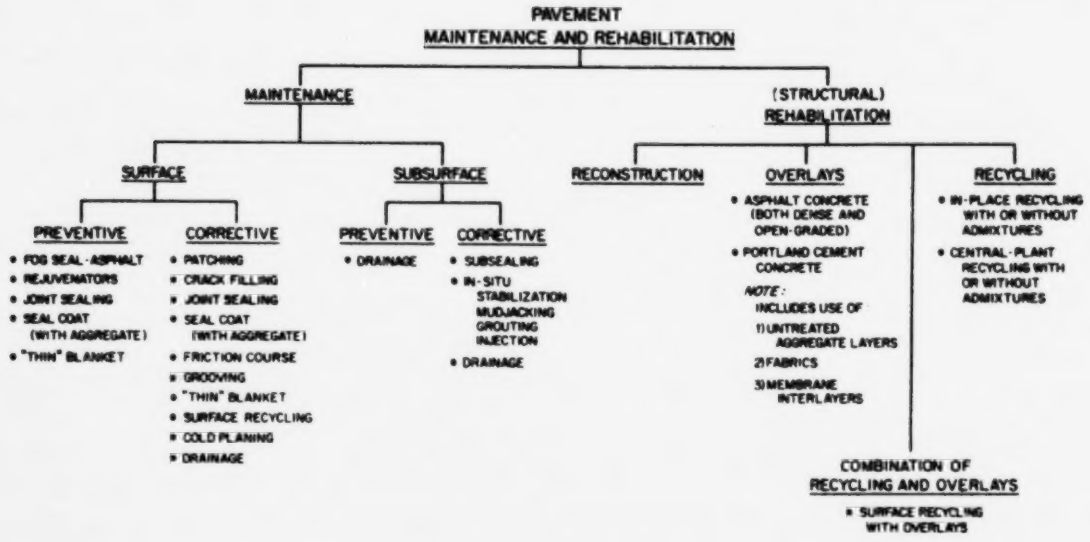

Figure 1/ Pavement Maintenance and Rehabilitation Considerations (from FHWA-TS-82-203, "Pavement Management: Procedings of National Workshops, June 1981)

The consultant's expertise now comes into play to estimate the effects any treatment will have on the subsequent condition index over the years. For example, a one-lift asphalt concrete overlay on a badly deformed roadway with a low condition index would not restore 100% of the functional or structural characteristics, and the road would deteriorate quite rapidly again to an action level. The consultant's expertise is needed to quantify the jump in condition index upon application of the treatment and the subsequent rate of deterioration of the index.

Another available strategy is the advancement or delay of the treatment by one or two years. Consultant expertise is again required to estimate the effects of such advancement or delay on the condition index.

Task 5/ Economic Analysis

One approach which can be taken is to first evaluate, for each section, the alternative treatments or treatment sequences over a period, in terms of their "benefit"/cost ratios to determine which alternative is most cost-effective, then to compile costs of these cost-effective treatments

into a needs statement with assigned priorities. This statement then can be divided suitably to reflect proposed budgets over five years, and at this time an appraisal can be made of the 'health' or average condition index of the network over five years (or 10 years) to estimate the impact of different budget options.

More comprehensive approaches would include consideration of advancing or delaying cost-effective and near cost-effective strategies and also include linear programming or other mathematical optimization techniques to make optimum use of available or proposed budgets with respect to 'benefits' or to condition index. As well, these more comprehensive system approaches can analyse impacts of different budget options and, conversely, can calculate optimized budget needs to attain and keep the system health at a given level.

The client agency can use any product of these different economic analyses. Since the analyses use average costs and predicted behaviour, one must expect a certain degree of adjustment to the plan, even after a number of years of fine-tuning. However, the systematic approach lends credibility to the results and justification for the budget.

The client agency may or may not wish to specify the economic analyses method, but it must specify what product is desired. For example:

a/ Given proposed budgets, tell me what optimum maintenance and rehabilitation plans can be made and what pavement conditions would result. or

b/ What unconstrained (or constrained) budget plan is needed to attain and keep a given condition index which I (or Council) will set?

Task 6/ Project Testing and Design

Once a priority list has been completed in Task 2, the processes of field investigation to collect data for detailed design can proceed. The design for some projects can readily follow the previous experience of the designer. For many projects on the priority list however, where not much is known of the history of the pavement, it is necessary to obtain such data from cores, boreholes, and deflection testing. Where projects require such data for design purposes, the data requirements can be specified in terms of the data needed, sampling frequency, time of testing, traffic control requirements, etc.

Where project pavement management services are needed to examine alternative treatments in more detail, more accurate estimated unit costs must be supplied to the consultant. The resultant more accurate estimate of the project cost must be used to replace and upgrade the Task 4 estimates which are input in the next year's Task 5 plan.

Thus, after the first two years of network planning, the projects in year 1 of the current year's network plan, the majority of projects in year 2, and some of the projects in year 3, will have estimated costs based on detailed project design and on more accurate unit price estimates; other projects (principally in years 3, 4, and 5 of the network plan) will have estimates based on average benchmark costs. Updated costs should be used for completed design projects which have been delayed but are still most effective treatment for the conditions.

- Payment for the specified work should be negotiated with the consultant:

  1/ Initial consultant time and cost are needed to work co-operatively with the agency to develop the appropriate systems structure, modelling data, etc., to establish the testing requirements, and to agree on outputs.

  2/ Training costs and time for both consultant and agency are needed to make the systems operate smoothly.

  3/ Consultant time for orienting the client with the outputs, including re-adjustments as needed.

  4/ Define the payment rates for each activity under each of the tasks.

  5/ Set out timeframes for the various tasks.

1.5/ Co-ordination of Programs

Pavement maintenance and rehabilitation management is just one input, albeit a most important one, to the development of overall budget proposals. There are, as well, work plans for other program items such

as structures and sewers which should be made to interact with pavement management plans to avoid as much as possible having to cut into pavements very soon after they have been rehabilitated, as this destroys the integrity of the pavement structure and hastens future rehabilitation; it also displays a lack of co-ordination with other services.

The time for co-ordination is when all needs have been assigned priorities and consideration is being given to the apportionment of funds.

1.6/ Concluding Remarks

Pavement management is a tool for municipal managers to provide their councils with pictures of the effects that changing expenditure on pavement maintenance and rehabilitation can have the projected condition of the road system over a period of years.

Pavement management service packages developed by consultants may contain optional features to improve accuracy of prediction, to assist in displaying programs, etc., which are additional to the basic products described above. The responsibility ultimately lies with the agency, and the agency must decide what services it needs.

Pavement management reliability improves as local experience with the system develops over the years, so it is essential to keep the data updated and current.

Pavement management consultants normally retain data on computer tapes and will permit a municipality access to these records through a remote terminal. Municipalities with their own computer equipment and staff should be able to acquire computer records and programs for in-house use in future years as needed.

The pavement management process is not limited to simply looking at the most effective deployment of agency resources for the rehabilitation of

pavements, it can also be used to consider the road-user cost effects on the community of delaying work or reducing standards.

The recommended pavement management system guideline is shown in Table 1 of the Executive Summary of this report.

Draft April 19/83

APPENDIX A/

A Review of Five Pavement Management Systems by the Municipal Engineers Advisory Committee, 1983

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A1/ INTRODUCTION

Pavements are a significant and very visible part of the roads and streets responsibility of local and regional municipal agencies. Pavement management systems provide the information and the analyses for optimized maintenance and rehabilitation strategies which will assist an agency to keep their roads and streets network in a 'healthy' condition.

Pavement management services are being offered by private sector consultants, and systems suitable for municipalities are under development and testing by the American Public Works Association (APWA) and by the Ontario Ministry of Transportation and Communications. The following systems were reviewed by the Municipal Engineers Advisory Committee set up to suggest guidelines for pavement maintenance systems for municipalities:

1/ **Novak-Dempsey method** -- presented by M. Gibson of Barker Terp Gibson Ltd., and by D. Hardt of Novak-Dempsey.

2/ **Edens method** -- presented by H. Edens of Gregg and Edens Ltd. in association with R. Gould and P. Bedell of Golder Associates.

3/ **PMS method** -- presented by D. Kobi and M. Karan of Pavement Management Systems.

4/ **PAVER method** -- presented by J. Emery and M. MacKay Trow Ltd., in association with M. Shahin Consulting Engineer.

The PARS method, under development by the Ontario MTC, was not reviewed by the committee, but is included in this record.

A2/ OBJECTIVES

During discussions of the Committee it was agreed that the products of a pavement management system which would be most useful to a municipality were the following:

1/ A computerized inventory of the physical characteristics, current condition, traffic volume, and other relevant data, for the pavements in the roads and street network.

The inventory can be used to provide a listing of priority projects for major maintenance and rehabilitation.

2/ For each project listed, the most cost-effective treatment is presented. Selection is made from a number of different alternative treatments, based on a measure of cost-effectiveness, or on a cost-optimization procedure. Detailed design of the project is not needed at this stage, so average estimated costs for each treatment type are used. Evaluation of alternatives may include interest and inflation rates, road user costs, traffic delay costs, etc., as desired.

3/ A Multi-Year Budget Plan (5-10 yr) is prepared. The plan can be derived with different objectives, such as optimum use of (assumed) available funds, or given serviceability or condition of health of system, etc.

The possibility exists to compare plans prepared with different objectives.

It was recognized that municipalities which undertook to use a pavement management system would need to provide some dedicated technical staff resources on an on-going basis, as well as the resources necessary for training, computer and other equipment as needed or desired, and for hiring consultant services as needed on a first-year basis and in subsequent years.

A3/ INVENTORY

The first step in developing an inventory is to divide the network into a number of discrete sections or links, which remain the same thereafter. The Edens and PARS methods recognize there is often need to shift the beginning or end points of projects thus creating changed sections or links.

The Novak-Demsey and PAVER methods further subdivide each section or link for purposes of detailed survey. The PMS method divides the network based on uniform pavement composition, traffic, age, geometrics, and drainage.

The second step is to collect relevant data (if available) on the construction history, such as pavement widths and thicknesses (design or actual), overlay thicknesses, construction dates (year), costs, and construction dates (year), costs, and maintenance costs. Traffic volumes and truck configuration data are always needed, and are usually provided by municipal forces. The Edens and PMS systems can utilize maintenance costs by section, if such costs can be derived from the maintenance management system.

There are minor differences among the various methods regarding the items which are recorded for inventory data.

A3.1/ The Current Condition Survey

All five methods use a visual condition survey, but there are major differences in the quantity and parameters which are observed and measured or subjectively assessed.

Novak-Demsey (Comprehensive Evaluation, 50 m Sections)

- Environmental Factors Survey (50 m sections, at walking pace)
  - site conditions, such as pavement width, frequency of driveways;
  - drainage conditions, curb and gutter, ditches, sub-drains;
  - shoulder conditions, paved, unpaved, depressed, grass;
  - water shedding capability, assessed on grade and crossfall.

- Traffic Volumes (by route length)

- Surface Study (by section), uses MTC Distress Manifestations Guidelines, but at walking pace:
  - surface defects
  - distortion
  - cracking
  - patching

  These are evaluated by weightings determined by Novak Dempsey.

- Dynamic Testing (50 m intervals)
  - Dynaflect (spreadability, SC1 calculated);
  - Benkelman Beam (as needed to determine correlation with Dynaflect).

- Structure Evaluation
  - coring (about 1 core per kilometre)

- Program I (comprehensive Evaluation Program output as follows):-
  - Surface Condition Number
  - Dynamic Pavement Condition Number (application of layer theory using Dynaflect results)
  - Deflection Pavement Condition Number (uses deflection, traffic)
  - Static Condition Number (uses pavement thicknesses and materials, and traffic)
  - Road Environment

  These are used to determine a composite "Present Pavement Condition Number" on a scale of 10 to 100, worst to best.

Edens (Variable length sections, identified by stationing along routes)

- Condition Rating (for each section)
  - Visual rating (based on scale defined by about 10 pictures).
  - Upgrading of rating scheme planned to make it compatible with Road Needs Study requirements.

- Pavements are classified to reflect structural design and typical links representing such classifications are selected. No deflection measurements are needed at this stage.

The ratings are used to provide data for a first iteration of the economic model. Output from this modelling analysis identifies high priority links (first three years of priority). The high priority links, typical links and links with abnormal deterioration rates could be selected for a more detailed data survey including coring and deflection testing either in conjunction with the condition survey or at a later date.

PAVER (Variable length sections, street blocks)

- Visual Condition Rating Survey (15% sample of approx. 30 m long sample units in a section for a typical 2-lane roadway)
  - Determine distress type, severity, and quantity of each distress type. A standard, comprehensive manual is used which defines 19 distress types, three levels of severity, and the method of measurement for both asphalt concrete and jointed concrete pavements.
  - Compute deduct values from standard curves.
  - Adjust total deduct value for number of deduct entries >5.
  - Compute pavement condition index for each sample unit inspected.
  - Compute average PCI for entire section.

- Structure Evaluation
  - Trow Ltd. believes the Falling Weight Deflectometer (FWD) best simulates the deflection of a moving wheel load, and uses the FWD to measure pavement deflection.
  - Coring is performed to supplement existing data or for in-depth evaluation of specific problems.

PMS (Variable length sections, street blocks)

- Ride, Condition, Geometrics (20/rural km, 50/urban km by ARAN or PURD)
  - Measured pavement roughness (accelerometer basis).
  - Visual assessment from moving vehicle of cracking distress, severity, and density, with keyboard input (uses MTC Manual and weightings).
  - Measured transverse profiles gives rut depths, cross-fall, etc.
  - Drainage evaluation.
  - Note location of bridges, culverts, etc.

- Structure Evaluation (Frequency increases for detailed project evaluation)
  - Dynaflect (10/km)
  - Coring (1/km)

Measurements made with ARAN or PURD are semi-automated for taped computer input. The survey data are translated into indices for Surface Distress, Riding Comfort. (Other indices are Structural Adequacy, and Pavement Quality). ARAN and PURD are both state-of-the-art devices engineered in Canada by Highway Products International, a company affiliated with PMS.

PARS (Variable length sections, street blocks)

This system is under development by MTC. Trials are currently underway in St Catharines.

- Ride quality measurements:
  - Mays Meter or other roughness meter.

- Visual condition (MTC Manual and Weightings):
  - surface defects
  - distortion
  - cracking
  - patching

- Traffic:
  - low
  - medium
  - high

Note: Work remaining to be done in PARS includes:
1/ reprogramming to make access on a terminal "user friendly"
2/ reformatting outputs for easier presentation,
3/ formalizing the procedures and preparation of training aids, and
4/ setting-up an MTC interface with municipalities who wish to use PARS on the MTC computer.

A3.2/ Inventory Output

The data resulting from this part of the system forms a computerized data bank arranged for easy retrieval for further processing. One of the products which can be produced is a list of projects which need to be looked at in greater depth and for which plans need to be made for rehabilitation, i.e., a list of work with assigned priorities. (Obviously there is some level of deficiency which cuts-off the list). Other products might be colour-coded maps, tables and histograms.

Significant computer hardware and software are needed at this stage and consultants have developed the knowledge and skills to service the products they offer.

A4/ CRITERIA FOR PRIORITIES

The criteria for determining when a length of road or street needs to be placed on the priority list vary with the system:

Novak-Dempsey -- When 25% of the 50 m sections making up the length of the road or street have deteriorated below an agreed condition index of, say, 70 on the 10 to 100 scale. Recognition is given to the probable reduction in estimated life of heavily-travelled roads.

Edens -- Edens uses a two-step approach. In the first step only links with a rating below an agreed value are considered as candidates for rehabilitation (for example, a rating of 60 for sections to be overlaid and 55 for reconstruction). In the second step, the priority of candidates is determined by a cost-effectiveness analysis which takes into account not only the rating of the links but also traffic volumes, interest rates and expected maintenance and construction costs.

PAVER -- Major maintenance and rehabilitation needs are determined based on the value of the Pavement Condition Index (PCI), distress causation, rate of deterioration, structural deficiencies, roughness, skid resistance, and previous maintenance. Levels of condition for rehabilitation are established with the municipality for the individual road classifications.

PMS -- Major maintenance and rehabilitation needs are determined based on the specific condition, ride, strength, or consolidated pavement quality index of the particular traffic class of the road or street.

PARS -- Similar to PMS.

Comment -- This priority list should perhaps agree with the work proposed by the needs study. However, it is known that the condition survey basis for the needs study attempts to define structural deficiency by visual observation. The condition surveys described for pavement management systems all attempt to define functional utility of the pavement. While it is desirable to be able to combine the two measures of deficiency (and therefore need), it is important to recognize that visual structural deficiencies usually occur at a late stage in the functional history of a pavement, and that some pavements show little structural deficiency even when they are functionally deficient.

A5/ COST-EFFECTIVE TREATMENTS FOR PROJECTS

There are two levels of accuracy required for determining the most cost-effective treatment for each project. At the network level when one is developing strategies and plans for keeping the total network in shape over a period of years, it is usually accurate enough to use average costs for different types of treatment and average predicted lives to determine which treatment is most suitable for a project. Obviously, though, the quality of prediction models used in this process is a key factor in the accuracy of the plans. At the project level, a very high degree of accuracy is needed to verify proposals for treatment made at a network level, and at this time many more detailed alternatives may be considered which could not very well be done at the network level due to lack of detailed information and lack of detailed testing including deflection analyses. As well, much more accurate cost estimates are prepared to take local factors into account.

All five of the systems discussed above use average costs for different treatments.

A5.1/ Prediction Models

The differences in the systems discussed above are in their prediction models.

The Novak-Dempsey method of prediction is based on experience gained by working on over 7000 km of roads and streets in all parts of North America. Their procedures, for which documentation has never been published, allow them to:

- forecast the improvement in rating level produced by any given treatment from surface treatment through to full reconstruct and subgrade treatment, for a pavement at a known prior rating, and
- forecast the expected life of the treatment, and as well provide some estimate of the level of expected maintenance over the years.

The forecast life is based on increasing geometric progression curves of deterioration rates. Eight years of records from 1975 have shown a high level of correlation with predictions. The procedures are proprietary to

Novak-Dempsey. The output of the computer program II "Pavement Improvement Evaluation", is a listing of the improved ratings for each treatment, for each 50 m section.

The Edens method utilizes visually derived 'cross-section' performance data (i.e., a plot is made of the condition vs age, of all road and street sections in the network). Limiting upper- and lower-bound envelope curves are developed. The concept for prediction which is used, is that any point plotted within the envelope will follow a future deterioration curve which is interpolated proportional to the upper- and lower-bound curves.

These concepts were developed for a set of uniformly designed pavements within Metro Toronto. Whether this experience can be translated to other areas and designs depends on local conditions regarding the mix of designs used in that locality. Where insufficient data are available due to either too few data points or due to lack of historical data, the curves will be estimated by using a Markov process. The prediction model would be upgraded when historical data become available.

The PAVER method of prediction is performed for each pavement section based on its original date of construction or overlay as well as subsequent condition (PCI) measurements. It uses a straight-line projection starting at a condition index of 100 at year 0, passing through the condition index Y at the survey age X, projected to whatever age is desired. The index for future years is read off the projected line. In subsequent years when more measured index points are plotted, other curve fitting techniques can be used to define the prediction curve. The method provides better accuracy than using one-regression models which represent an average pavement and not the individual pavements in the network considered. As large amounts of data are collected through APWA, continuous refinements in the techniques are expected.

In the PMS method of prediction, unique deterioration curves are developed for different rehabilitation and maintenance treatments by asking appropriate questions of experienced local engineers and construction and maintenance staff, regarding their observations on pavement behaviour over time (Markov process). Subsequently, when measured performance data

become available, this actual experience can be incorporated into the deterioration curves if deemed necessary. The experience with verification of this technique to date has been good, with better than 80% success (after the first-year interation), in one case documented five years later. The basic output tabulates, for each section in the network, the year in which the pavement becomes unacceptable.

The PARS method also uses a Markov process for development of unique deterioration curves.

A5.2/ Alternative Treatments

The Novak-Dempsey, the Edens, and the PMS systems, use treatments generally considered as major maintenance or rehabilitation treatments, such as hot-mix patching, surface treatments, slurry seals, overlays of different thicknesses and, more recently, recycling options. In addition, the PAVER and PMS systems include other maintenance treatments such as hot- or cold-mix patching, spray patching, and crack filling.

In the Edens system, a sequenced pattern over time of major maintenance, rehabilitation, and reconstruction activities for any class and design of link is set by considering past experience. These patterns are used when the economic model is applied solely as a financial planning tool, e.g., to determine required future budgets used for a first iteration. In that case, the first three years of the priority listing are considered high priority links. From these, a selection is made for surveying in greater detail including, as required, boring and deflection testing. Based on the more detailed surveys, rehabilitation plans are developed for those links. When more than one treatment for a link is considered, the dominant alternative is selected based on cash flow analysis.

The design procedures will result in more accurate costs and life expectancy estimates and this data now replace the original sequenced pattern in the model for the links in question. After rerunning the model, the first year's priority list can be set. One has a choice to base this list on a given budget or on the requirement to maintain a given network quality. The process is repeated a year later. At that stage, two-

thirds of the high priority links would have been surveyed and designed previously, and approximately one-third would require the above design procedures. Designs would be re-examined if experiences show that budgets are significantly different from anticipated levels.

In the Novak-Dempsey system, while there are some 80 different treatment options possible, only up to nine treatments are considered for any project at any time over the planning period. In the PAVER system, guidelines and a select list of rehabilitation alternatives are provided by the program. In the PMS system, all the alternatives are examined over the analysis period and the treatment sequence is selected on either maximization of benefits or minimization of costs. In the PARS system, a dominant strategy selection is made to reduce the volume of calculations.

A5.3/ Costs, Evaluation, and Optimization

At the network level, all systems use average construction costs in their economic analyses of alternatives. These costs are generally based on client data available from previous contract or direct labour work.

To evaluate between alternatives, the Novak-Dempsey system calculates for each treatment, the cost per square metre divided by the number of years of life the treatment is expected to last. The 'cost per square metre per year of benefit' for the current year and each of the next five years is calculated using agreed inflated unit costs, and the predicted years of life of the treatment allowing for the further deterioration of the section. In listing these results, the treatments are arranged by increasing unit cost from left to right of the page, and by years beginning at the top line. Against each "cost/square mile/year of benefit", a notation is made indicating the degree of success of the treatment to improve the condition index to some agreed new level, such such as 85 to 90 (i.e., the treatments which must be 'rejected' as unsatisfactory are identified). The cost-effective solution is in the column to the right of the 'rejected' alternatives. The most cost-effective year to apply that treatment is identified by the lowest cost/square mile/year value in the column. The so-called 'optimized' plans for the next five years can thus be identified and listed, and the funding requirements determined. Other 'less-than-optimum' plans can also be compiled to satisfy budget constraints.

Comment -- The method of presenting the cost/benefit values for each treatment type together with their degree of success in restoring the condition number and the year for which the cost/benefit is 'optimized', makes this system easy to explain and simple to use. It requires a 'manual selection' input in the preparation of the plan, which is attractive because it permits a degree of decision-making by the client agency's staff.

The Edens system has a more sophisticated method of economic analysis. The cost of future reconstruction, overlays, and preventive maintenance for each link are established by means of applying predictive relationships of condition and maintenance with respect to age -- considering the agreed pattern of reconstruction, and overlays or other rehabilitation, and considering where designs are based on detailed surveys. The present value of costs for the stream of future costs for each link is calculated, based on an agreed discount rate. The calculation is repeated for a year later (or more than one year), assuming that construction has been delayed for that year. To evaluate the comparative benefits of spending funds on different links in a network, each link has a Distress Index calculated, which is the deviation of the condition rating below a standard or agreed rating value weighted by the length of the road link and by the traffic volume (i.e., the distress index represents the cost to the road user of travelling over sub-standard roads). Through use of predictive condition equations, the distress index for each of the future years under examination can be determined. The difference in distress index between two consecutive years divided by the cost differences (determined earlier) between the same years provides the measure of relief of distress which can be bought by spending dollars to advance construction by one year. By selecting those links that buy the most "distress relief per dollar spent", the use of the budget will be optimized.

In the PAVER system, a schedule of maintenance and rehabilitation activities based on the condition index and on the specific distress types observed, has to be formulated (by the agency) for each link with the aid of an Evaluation Summary Report (developed based on input from many experienced maintenance engineers). The costs and timing of each of these activities, which can be varied as needed to examine their effect

on costs, is input to an economic analysis program which calculates present value, and equivalent uniform annual costs per square yard. This program allows the user to vary discount rates, inflation rates, repair costs and timing, thus permitting evaluation of alternatives on the basis of lowest equivalent uniform annual cost per square yard. The evaluation is done interactively on the computer on a project-by-project basis.

Note -- Additional programs are now available to predict improvement in condition index after application of a given treatment, and for the optimization of a budget.

The PMS and PARS systems use sophisticated programming techniques to examine, for each project, the costs and effects on predicted performance of accelerating or delaying the project in any year over a five- or 10-year program period using all of the different rehabilitation treatments agreed on (i.e., five or ten costs and effects for each treatment). As well, the PMS system calculates both the user cost savings accrued by vehicles operating under improved conditions for the selection of project strategies to maximize benefits, or the optimum solution for minimum cost, while the PARS system uses the area under the performance curve, PCR vs Age, as a measure for maximization. Mathematical optimization techniques are used in PMS systems for optimization (similarly PARS uses linear programming). That is, selection is made of the projects and the treatment and year which add up to an assumed budget and which produces the highest benefits. Selection can be made with constrained or unconstrained budgets, with constant budgets, or budgets varying at a given rate over the 10-year period, or by minimizing costs.

A6/ FINANCIAL PLANNING

The Novak-Dempsey system has a built-in capability to select, through inspection, either those cost-effective alternatives which lead to an "optimized" plan, or those less-than-cost-effective alternatives of lower initial cost which satisfy budget constraints, and which lead to a least-initial-cost plan. This is called the Comprehensive Management Program, which can only be done when full data collection is available.

However, a similar planning capability is available in the network management system which uses less detailed data.

The Edens method optimizes the budget by selecting the projects that buy the most distress relief per dollar spent. However, additional criteria for compiling the plan for any year may be applied (such as setting a minimum distress level). One of the features of the Edens system is that it traces over time the effect of changing budget level on the overall or averaged condition of the network. This is a feature already available from both the PMS and PARS systems, which gives the manager more confidence in requests for funds to rehabilitate and maintain his network over a period of years, either within a predetermined budget level or at a predetermined level of condition index.

The PAVER system has a five-year budget planning report which estimates needed funds for selected minimum conditions for the various pavement functional classifications. The report has recently been updated to allow the user to vary minimum acceptable conditions over time so as to achieve a practical financial plan for gradual upgrading of the condition of the pavement network.

The PMS system can optimize by either minimizing agency costs to achieve performance standards or maximizing road user benefits while staying within annual budget constraints. The PARS system optimizes by maximizing performance ('health') of the system. Five- or ten-year financial plans can be developed with different objectives such as constant, decreasing, increasing or unconstrained budgets, or different performance standards for the system.

A7/ COSTS

The costs of each of the systems are quite different, depending on the amount of work (detail) required to collect input data, and on whether the output was financial planning for a network, or project priorities or life-cycle costing. As indicated earlier in the report, the level of detail believed to be necessary to provide the two different types of output also varied from system to system.

Costs appear to vary from about $100 to $250/km for network financial planning where the consultant carries out the bulk of the work (there is a client cost of about $15 to $20/km for supplying part of the required data). The PAVER system is non-proprietary and is supported by APWA. As such, there are no user fees, and reduced rates for computer time are provided. Costs for the more detailed data collection required for project planning and setting of priorities can be perhaps 10 times the cost of network financial planning, depending upon the particular system. Often, the cost of this detailed data collection is more than offset by design savings.

A8/ AGENCY INVOLVEMENT

There is a need, in any agency undertaking to use a pavement management system, to have at least one staff member dedicate a major portion of his time to the tasks of planning the work, co-ordinating the data collection, verifying the data, familiarizing himself with all aspects of data handling and manipulation, supplying data on costs, discount rates, etc.

It is now feasible for even a small agency to afford its own computer or intelligent terminal. Once a system has been implemented, any of the consultants can supply at least part of the software needed to process the inventory data. (The Novak-Dempsey software for prediction modelling is not made available to clients.) Alternatively, access to the computers used by the consultant can in most cases be arranged over the 'phone lines. Direct access to the PAVER system can be made through the APWA.

If the agency wishes to undertake a more active part in the determination of condition index, any of the consultants is prepared to offer training. An understanding of the condition survey procedures is essential to the agency even if consultants do the actual work.

A9/ CONCLUDING REMARKS

The five pavement management systems described briefly above have been fitted into a framework for purposes of comparison. By doing this, some of the qualities of some of the systems may have been unintentionally omitted. Also, these systems are being continually upgraded, so that these descriptions may be outdated in one or two years.

The purpose of this review is to provide background material to structure a set of guidelines for municipalities who propose to use pavement management now.

APPENDIX B/

INVENTORY MANUAL

MUNICIPAL ROADS AND STRUCTURES

July 1978

Hon. James W. Snow
Minister

H. F. Gilbert
Deputy Minister

ITEM (52) SURFACE CONDITION - Maximum Points 10

This relates to driving ease, comfort and safety. Inadequacies on paved surfaces include excessive or uneven crowns, washboarding, ravelling and bumpiness because of cracking, sealing and rough patching. Inadequacies on loose-top surfaces do not include situations that can be readily corrected by maintenance blading. They do include unconsolidated surfaces due to poorly graded or clean aggregate, or permanent roughness due to insufficient depth of aggregate or weak subgrade. Inadequacies on earth roads are those qualities inherent in the character of the soil that cannot be eliminated by blading. The effects of surface inadequacies in ascending order of seriousness are noise, vibration, sway, excessive steering effort, and finally, reduced speed.

The existing conditions should be rated as follows:

Condition	Points
If the section affords a fully adequate standard of service, and it is possible to maintain at least the minimum tolerable average safe speed (see Item 60) or legal speed limit (see Item 20) whichever is the lesser, with no annoyance or discomfort, assign:	10
If it is possible to maintain the minimum tolerable average safe speed or the legal speed limit whichever is the lesser on the section, but with a noticeable amount of annoyance to the driver due to sway, vibration, or steering effort, but no noticeable feeling of hazard, assign:	7
If maintaining even the minimum tolerable average safe speed or legal speed limit whichever is the lesser, results in either a "tug-of-war" with a too-steep or uneven crown, or a feeling that the car is taking undue punishment, assign:	4
If the surface irregularities are so severe that a driver will tend to reduce speed considerably, possibly even steering an irregular course, or if the crown is so steep as to be hazardous in winter, assign:	0

Point rating other than the above will allow for minor variations in the described conditions. Where the surface condition varies widely along a section, it should be rated on the basis of the worst conditions that exist over 30% or more of its length.

ITEM (53) SHOULDER WIDTH - Maximum Points 10

A. URBAN SECTIONS - Spare. Enter Zeros in the two boxes provided.

B. RURAL AND SEMI-URBAN SECTIONS

Refer to the existing Shoulder Width as already recorded (Item 24) and compare this to the shoulder width for the appropriate jurisdiction, existing class and terrain (for rural road sections), or to the appropriate functional classification and parking condition (for semi-urban road sections), and assign points from the appropriate table below. To use these tables enter the column for the appropriate existing class and terrain or functional class and parking condition and compare the existing shoulder width to the values shown. Assign a point rating as indicated, interpolating as necessary. Note that all widths shown in metres and tenths include rounding. Road sections with MODIFIED APPRAISAL, assign maximum point rating (10 points).

(a) RURAL SECTIONS

(i) <u>County Jurisdiction</u>

		EXISTING CLASS				
TERRAIN	POINTS	0-400	400-1000	1000-2000	2000-3000	3000+
Flat	10	1.5	1.5	2.5	2.5	3.0
	5	1.2	1.2	1.5	1.5	2.0
	0	0.5	0.5	0.5	0.5	0.5
Rolling	10	1.2	1.3	2.5	2.5	3.0
	5	1.0	1.0	1.5	1.5	2.0
	0	0.5	0.5	0.5	0.5	0.5
Rocky	10	1.2	1.2	2.0	2.0	2.5
	5	1.0	1.0	1.2	1.2	1.5
	0	0.5	0.5	0.5	0.5	0.5

(ii) Local Jurisdiction

TERRAIN	POINTS	EXISTING CLASS 0-400	400-1000	1000-2000	2000-3000	3000+
Flat	10	1.5	1.5	2.5	2.0	3.0
	5	1.0	1.0	1.5	1.5	2.0
	0	0.5	0.5	0.5	0.5	0.5
Rolling	10	1.2	1.2	2.0	2.0	2.0
	5	1.0	1.0	1.2	1.2	1.5
	0	0.5	0.5	0.5	0.5	0.5
Rocky	10	1.2	1.2	2.0	2.0	2.0
	5	1.0	1.0	1.2	1.2	1.5
	0	0.5	0.5	0.5	0.5	0.5

(b) SEMI-URBAN SECTIONS

(i) Without Parking

FUNCTIONAL CLASSIFICATION	loc. R	Loc. C+I	Coll. R	Coll. C+I	Art.
Points 10	1.5	2.0	2.5	3.0	3.5
Points 7	1.2	1.5	2.0	2.5	2.7
Points 3	1.0	1.2	1.5	2.0	2.0
Points 0	0.5	1.0	1.0	1.5	1.5

(ii) Parking Permitted

FUNCTIONAL CLASSIFICATION	Loc. R	Loc. C+I	Coll. R	Coll. C+I	Art.
Points 10	1.5	2.0	2.5	3.0	3.5
Points 5	1.2	1.5	2.3	2.8	3.0
Points 0	1.0	1.2	2.0	2.5	2.5

ITEM (54) STRUCTURAL ADEQUACY Maximum points 20

This relates to the load supporting ability and resistance to deformation or rupture of the surface and base course.

For loose top roads, distress signs are limited to soft spots and frost boils.

For paved surfaces, distress signs may be cracking, rutting, heaving, pot-holing, roughness, alligatoring, dishing, breakup, distortion, frost boils, etc.

NOTE: Do not equate riding quality with structural strength. A paved surface may have a poor riding quality because of the roughness of previous patching, yet be structurally adequate at present. A loose-top surface may have poor riding quality because of inadequate blading, yet be capable of carrying the imposed traffic. Also, a surface may ride smoothly but, on close examination, show surface cracking or unevenness in cross section indicating structural weakness and impending failure.

In all cases record the year that this item is appraised in the space provided in Item 62, Structural Adequacy deficiency, as indicated by the asterisk.

A. LOOSE TOP SECTIONS

A section is to be appraised on the basis of two conditions existing during the spring. They are (a) soft spots as indicated by rutting and frost boils, and (b) frost boils alone. Frost heaving which does not lead to boils is to be ignored. Each condition is to be appraised separately and the lower of the two point ratings is to be used.

(a) Soft Spots: (Include the length of frost boils)

Condition	Points
Less than 5% of the length of the section.	20
From 5 to 15% of the length of the section.	15 to 19
From 15 to 20% of the length of the section.	12 to 14
From 20 to 25% of the length of the section.	8 to 11
More than 25% of the length of the section.	7 or less

Suitable variations in the point rating will allow for variations in the percentages.

(b) Frost Boils: (Exclude the length of soft spots which do not boil.)

Condition	Points
No boils.	20
Less than 5% of the length of the section.	15 to 19
From 5 to 10% of the length of the section.	12 to 14
From 10 to 15% of the length of the section.	8 to 11
More than 15% of the length of the section.	7 or less

Suitable variations in the point rating will allow for variations in the percentages. However, if the point rating is between 8 and 14 inclusive a spot improvement may be warranted. If so, show the appropriate information for the spot improvement under Type, Cost and Time of Improvement.

B. HARD TOP SECTIONS

In examining hard top sections, the type of the distress sign should be considered as well as the frequency of occurrence. Some types of pavement failure may not reflect the structural adequacy of the road. For instance, transverse cracking may be because of insufficient bearing support or because of fill shrinkage. In the latter case, the defect is not serious and crack filling or resurfacing should eliminate the problem.

The following are typical surface defects which shall not be considered when evaluating the structural adequacy, bleeding, ravelling, pitting, stripping, slight alligatoring, reflection cracking, edge cracking, and shrinkage cracking. In general, surface defects which could be corrected by proper maintenance or resurfacing procedures shall be ignored. For concrete pavements, defects such as scaling, flecking, alligator cracking, hair checking, crazing, pockmarking, honeycombing, polishing, pitting and spalling shall also be ignored.

Condition	Points
Signs of surface distress represents less than 5% of the length of the section.	20
Distress is noted on from 5 to 10% of the length. The required maintenance effort may be above average but not uneconomical when compared to the cost of reconstruction.	15 to 19
Distress is noted on from 10 - 15% of the length. Again the required maintenance effort may be above average but not necessarily uneconomical when compared to the cost of reconstruction.	12 to 14
Distress is noted on from 15 - 20% of the length and the required maintenance effort is high.	8 to 11
Distress is noted on more than 20% of the length of the section and the required maintenance effort is excessive.	7 or less

Suitable variations in the point rating will allow for variations in the percentages. However, in certain instances, a spot improvement may be warranted for a section rated over 15 points. If so, show the appropriate information for the spot improvement under Type, Cost and Time of Improvement.

[ ][1][ ] UPDATE CODE

MUNICIPAL ROAD SECTION – APPRAISAL SHEET

CONTROL [ ][ ][ ][0][1]

IDENTIFICATION

(1) MUNIC _____ [ ][ ][ ][ ]

(2) ROAD DESCRIP 'ST NAME _____

(3) FROM _____ (4) SECTION NO [ ][ ][ ][ ][ ]

TO _____ (5) LENGTH [ ][ ][ ].[ ] km

6 SPARE _____ (7) ROADSIDE ENVIRON: RURAL(1) SEMI-URBAN(2) URBAN(3) [ ]

(8) ADJAC MUNIC _____ (10) BOUNDARY ROAD YES___NO ___

(9) ADJAC MUNIC ROAD SECTION NO. [ ][ ][ ][ ][ ] 11 PRES JURIS. MTC (1) CO. (2) LOC. (3) [ ]

(15) STRUCT NO _____ 12. DESIRABLE JURIS CO. (2) LOC. (3) [ ]

(16) RWY X ING NO _____ 13. PRES. DESIG. SUB. RD (1) MTC C.L. (2) CO. C.L. (3) [ ]

17 SPARE _____ 14 SUB. COMM. NAME _____ [ ][ ]

18. SPARE _____

EXISTING CONDITIONS & ADEQUACY RATINGS

(19) EXISTING CLASS. _____ [ ][ ]

20. SPEED ZONE _____ km/h 23 PLATFORM WIDTH _____ m (25) SURFACE TYPE _____ [ ]

21 AVGE SAFE SPEED _____ km/h 24. SHOULDER WIDTH _____ m 26. SURFACE WIDTH [ ][ ].[ ] m [ ]

22 TERRAIN FLAT _____ 27. TRAF. OPER. ONE WAY ____ TWO WAY ____ (28) NO. OF LANES

ROLLING _____ 29. DIVIDED YES ____ NO ____ MEDIAN WIDTH [ ][ ].[ ] m

ROCKY _____ 30. TRAFFIC SIGNALS YES ____ NO ____ 31. RIGHT OF WAY WIDTH [ ][ ].[ ] m

(32) BUS ROUTE YES___NO___

33 HORIZ ALIGN NO. OF SUBSTANDARD CURVES _____ 35. SIDEWALK WIDTH: LEFT ____ m RIGHT ____ m

NO. OF SUBSTANDARD S.S.D. _____ 36. BOULEVARD WIDTH: LEFT ____ m RIGHT ____ m

34 VERT ALIGN NO. OF SUBSTANDARD GRADES _____ 37. CURB TYPE: BARRIER ____ MOUNTABLE ____ OTHER ____

NO. OF SUBSTANDARD S.S.D. _____ 38. SPARE _____

39 PARKING: LEFT RESTRICTED YES ____ NO ____ RESTRICTIONS _____

RIGHT RESTRICTED YES ____ NO ____ RESTRICTIONS _____

(40) DRAINAGE DITCHES _____ STORM SEWERS _____ COMBINED SEWERS _____

41 19___ TRAFFIC DHV _____ % _____ VPH DIRECT. SPLIT _____ TRUCKS _____ % AADT [ ][ ][ ][ ][ ]

42 CAPACITY (LEVEL 'E' VOLUME) INTERSECT. APPROACH VOL. _____ MID BLOCK VOL. _____

43 10 YEAR GROWTH FACTOR _____ 44 SPARE _____

45 19___ TRAFFIC DHV _____ % _____ VPH DIRECT. SPLIT _____ TRUCKS _____ % AADT [ ][ ][ ][ ][ ]

46 TRAFFIC COUNT LOCATION CODE NO [ ][ ][ ][ ][ ][ ] 47. SPARE _____

POINT RATINGS

					EXIST COND.	MIN. TOL.	NOT DEF.	DEFICIENT NOW	DEFICIENT 1–5	DEFICIENT 6–10
(48) LEVEL OF SERVICE	[ ][ ]	OUT OF 20	**DEFICIENCIES**							
49. HORIZ. ALIGNMENT	[ ][ ]	OUT OF 10								
50. VERT. ALIGNMENT	[ ][ ]	OUT OF 10	(58) SURFACE TYPE							
(51) SURFACE WIDTH	[ ][ ]	OUT OF 15 R&SU OUT OF 25 URB	59. SURFACE WIDTH							
(52) SURFACE CONDITION	[ ][ ]	OUT OF 10	60. AV. SAFE SPEED							
(53) SHOULDER WIDTH	[ ][ ]	OUT OF 10 R&SU ONLY	61. LEVEL OF SERVICE		E					
(54) STRUCTURAL ADEQUACY *	[ ][ ]	OUT OF 20	(62) STRUCT. ADEQ.	*19___						
(55) DRAINAGE	[ ][ ]	OUT OF 15	(63) STORM SEWER ADEQ.	19___						
(56) MAINTENANCE DEMAND	[ ][ ]	OUT OF 10								
(57) CONDITION RATING *	[ ][ ][ ]	OUT OF 100								

64. ACCOMPLISHMENT CODE (MTC) [ ][ ]

TYPE, COST & TIME OF IMPROVEMENT

(65) TYPE OF IMPROVEMENT [ ][ ]

A CARRY OVER ___
B SPOT ROAD ___
C SPOT DRAINAGE ___
D RESURFACING ___

RURAL

E BASE & SURF (TOL ST'D) ___
F BASE & SURF (DESIGN ST'D) ___
G RESURF & WIDEN (TOL ST'D) ___
H RESURF & WIDEN (DESIGN ST'D) ___
I RESURF & WIDEN (4 LANES) ___
J RECONSTRUCTION ___
K NEW CONSTRUCTION ___

SEMI-URBAN/URBAN

L BASE & SURF (MINOR) ___
M BASE & SURF (MAJOR) ___
N RESURF & WIDEN (MINOR) ___
O RESURF & WIDEN (MAJOR) ___
P RECONST (SEMI-URBAN ST'D) ___
Q RECONST (URBAN ST'D-NOMINAL S.S.) ___
R RECONST (URBAN ST'D-INCLUD S.S.) ___
S STORM SEWER & ROAD REINSTATEMENT ___
T NEW CONSTRUCTION ___

(79) MUNIC PERCENT OF SUBSIDIZABLE COST _____ %

80. DESIRABLE JURISDICTION _____ %

(66) DESIGN CLASS _____

(67) IMPROVEMENT LENGTH [ ][ ].[ ] km

(68) TIME NOW (1) 1-5 YR (2) 6-10 YR (3)

(82) REMARKS _____

81 YEAR LAST IMPROVED _____

OF IMPROVEMENT _____

83 PRIORITY RATING

84 PRIORITY GUIDE NO

85 COST/VEH km [ ][ ].[ ] ¢

(86) DATE _____

(87) BY _____

COSTS IN $ THOUSANDS

COSTS	
(69) RIGHT OF WAY	[ ][ ][ ][ ]
(70) CONSTRUCTION	[ ][ ][ ][ ]
(71) STORM SEWERS	[ ][ ][ ][ ]
(72) CULVERT	[ ][ ][ ][ ]
(73) SIDEWALK	[ ][ ][ ][ ]
(74) RWY X ING	[ ][ ][ ][ ]
(75) OTHER	[ ][ ][ ][ ]
(76) TOTAL COST	[ ][ ],[ ][ ][ ]
(77) NON-SUB COST	[ ][ ],[ ][ ][ ]
(78) SUB COST	[ ][ ],[ ][ ][ ]
	[ ][ ],[ ][ ][ ]
	[ ][ ],[ ][ ][ ]

(7) RURAL [ ] SEMI URBAN [ ] URBAN [ ] (4) SECTION NO [ ][ ][ ][ ][ ]

OD-MB-175M 78-07

POOR

QUALITY

ORIGINAL